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Nitrous Oxide Use For Minor But Painful Pediatric Procedures

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NITROUS OXIDE USE FOR MINOR BUT PAINFUL PEDIATRIC PROCEDURES

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By

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Abstract

Problem: Nitrous oxide (N_2O) is used for mild to moderate pain control and anxiolysis. Registered nurses (RN) as providers of N_2O administration may decrease the number of missed opportunities for pain control or anxiolysis. The purpose of this quality improvement initiative was to evaluate the type of procedures and rate of N_2O administration by providers, and cost difference between them.

Method: A descriptive, cohort-design for pediatric patients in the Imaging and Sedation Department between October through November of 2017 and 2018. Data was compared between physicians in 2017 and either a physician or RN administered gas in 2018.

Results: A total of 197 (N=197) patients received N2O. In 2017, there were 93 patients (n=93) and in 2018, there were 104 patients (n=104). In 2017, only physicians (n=93; 100%) delivered the gas. In 2018, 41 RNs (n=41; 39%) and 63 physicians (n=63; 61%) delivered the gas. The difference between providers was not significant (t=2; p = .875); hence, the addition of RNs did not change the number of patients receiving N_2O. The most common procedure for physician delivery was botox injection while the most common procedure for RNs was intravenous catheter insertion. Finally, reimbursement was greater when a physician delivered the gas versus the RN.

Implications for Practice: The number of administrations by physicians decreased once RNs were administering N_2O. However, there was still an increase in the amount of pediatric patients receiving N_2O between the two cohorts studied. The use of N_2O in minor but painful procedures is encouraged.

Nitrous Oxide Use for Minor But Painful Pediatric Procedures

Nitrous Oxide (N_2O) is a colorless gas mixture of nitrogen and oxygen administered through a mask, and is used for minimal sedation, pain control or anxiolysis. Frequently used in dentist offices and by anesthesia teams, N_2O is useful for minor procedures not requiring an operating room. In the pediatric population, N_2O has become increasingly common for minimally invasive, but painful or anxiety producing procedures (Farrell, Drake, Rucker, Finkelstein, & Zier, 2008). Examples of some procedures are: intravenous catheter (IV) insertions, lumbar punctures (LP), botox injections, suturing, foley catheter placements, and more. The procedures listed may cause pain and/or anxiety to pediatric patients, leading to a poor patient experience and potentially a poor outcome from the procedure itself (Pedersen, Bayat, Steen, & Jacobsson, 2013).

Considered a safe form of sedation, N_2O often has no major adverse effects, but minimal effects when the length of the procedure extends beyond 10-15 minutes (Livingston, 2016). Friedrichsdorf (2017) found no correlation between adverse effects and the percentage of N_2O being used, adding that the percentage of N_2O can be titrated to the desired effect, usually between 40-70%. Furthermore, minimal monitoring of patients undergoing procedures with N_2O is required by a registered nurse (RN) to monitor pulse oximetry and heart rate until the patient has fully recovered (Friedrichsdorf, 2017). Appropriate mask size and a system in place to capture exhaled gas or aerosolized medication (i.e., scavenging system) to prevent inadvertent inhalation by others are of importance to maintaining safe use of nitrous oxide (Livingston, Lawell, & McAllister, 2016).

The administration of N_2O is commonly done by a physician, dentist or other healthcare provider such as an advanced practice registered nurse (APRN), physician assistant (PA), or anesthesia assistant (AA). Throughout the U.S., hospitals are establishing credentialing programs and policies pertaining to the administration of N_2O by RNs. At the Children's Hospitals and Clinics of Minnesota, Dr. Judith Zier (founder of the Zier group) has facilitated more than 10,000 pediatric patients receiving N_2O for procedures and developed a training program for other healthcare providers to safely use this method for minimizing pain and anxiety related to minor procedures (Ziergroup.com). Credentialing RNs to deliver N_2O may increase the number of patients who receive pain control or anxiolysis.

The purpose of the hospital's quality improvement (QI) initiative was to increase the use of N_2O for minor, brief, but painful or anxiety-producing pediatric procedures at a Midwestern, urban, pediatric medical center. Currently, only physicians are credentialed to deliver N_2O during these procedures at the medical center. Because of this, there were a number of missed opportunities to minimize pain or anxiety with N_2O. The overall aim of this project was to evaluate the increased number of providers available to assist in pain management during procedures when RNs were credentialed to deliver N_2O. The questions for study included: In a Midwestern pediatric medical center,

1. what were the most common pediatric procedures requiring N_2O use?
2. what were the number of minor, painful pediatric procedures performed using N_2O from October 1st, 2017 through November 30th, 2017 (physician providers only) when compared to October 1st, 2018 through November 30th, 2018 (physician and RN providers).

3. what was the rate of N_2O delivery by a physician when compared to an RN from October 1st, 2018-November 30th, 2018?
4. what was the average financial cost of N_2O administration by a physician provider when compared to an RN provider?

Literature Review

A literature search included the CINAHL, MEDLINE, and PsychINFO search engines. Search terms were *nursing, nitrous oxide, children, pediatric, hospital, intervention, and procedure*. Inclusion criteria were studies of the pediatric population, RN-delivery of N_2O, peer reviewed research, written in English and published within 10 years (January 2008 to October 2018). Exclusion criteria were publications in any language other than English, published before January 2008, publications based on expert opinion, or publications using non-RN delivery of N_2O. A total of 20 publications were retrieved, and 10 of these were selected for this review.

The concept of pediatric pain has been controversial but treatment and management of pediatric pain has improved in the last 20 years. Despite advances, pediatric patients remain under treated when compared to adults (Emons, Petzke, Stamer, MeiBner, Koschwitz, & Erlenwein, 2016). Common reasons for avoiding pain control in children include an uncertain level of pain being experienced and a fear of overdosing a child (Emons et al, 2016). In Germany, Emons et al. (2016) found only 76% of the hospitals studied provided pain management for procedures such as IV insertions, dressing changes, and blood draws.

Pediatric sedation ranges from minimal to deep sedation, or general anesthesia. Minimal sedation might include the use of N_2O and is the least invasive form of sedation.

Minimal sedation requires monitoring by pulse oximetry, has minimal to absent adverse effects, and has a quick recovery time. Moderate sedation would consist of medications and medication dosages that cause the patient to have decreased consciousness but able to respond to verbal commands (Huang, Johnson, 2016). Monitoring of a patient's heart and respiratory rates, blood pressure, and pulse oximetry due to increased adverse effects and prolonged recovery times are required (Hazwani, Al-Alem, 2017). Deep sedation, defined as a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation, utilizes medications such as propofol (anesthetic) and is commonly used in pediatric sedation (Kang, Shin, Gil, Kim, Yeo, & Jeong, 2017). The use of propofol requires the administration of oxygen and monitoring to include heart and respiratory rates, blood pressure, and capnography (Kang et al., 2017). The difference between deep sedation and general anesthesia is the ability for one to maintain their own airway. Under general anesthesia, the use of an artificial airway (e.g., endotracheal tube or laryngeal mask airway) is required.

The use of N_2O began in the mid-1800's. A dentist by the name of Horace Wells was the first to learn N_2O could be used in an inhaled form of sedation in 1844. In collaboration with his colleague John Riggs, N_2O was used successfully to remove a wisdom tooth (Berthelsen, 2016). Despite this early success, N_2O was not routinely administered until the 1930's for childbirth pain, and in the 1960's for dental procedures (Zuck, 2012). N_2O administration for children also began in the dentist's office in the late 1900's; however, N_2O is now frequently used for children in hospitals for pain

management because of its minimal side effects and short recovery time (Martin, Noble, Wodo, 2015).

The administration of N_2O is frequently used in health care for minor but painful or anxiety-producing procedures. Farrell, Drake, Rucker, Finkelstein, and Zier (2008) created a program for RNs to administer N_2O at a pediatric hospital. Training for N_2O is often referred to as the "Zier group," and was named after Dr. Judith Zier who was a founding physician and author of N_2O training for RNs. The Zier group created an on-line course for N_2O administration. Reported advantages of N_2O when compared to moderate or deep sedation methods included rapid onset and rapid recovery, a continued state of consciousness, and minimal adverse effects (Farrell et al., 2008). The Zier group also discussed less, but necessary monitoring for patients undergoing N_2O sedation, including nursing observation and pulse oximetry during sedation and recovery (Farrell et al., 2008).

When N_2O is used, minimal adverse effects enhance patient satisfaction. The most common adverse effect reported is nausea and/or vomiting, and can occur if the N_2O is used beyond 10-15 minutes (Zier, Rivard, Krach, & Wendorf, 2008; Livingston, 2016). Zier et al. (2008) compared N_2O to intranasal Midazolam for pediatric BOTOX injections, resulting in several pediatric patients experiencing one or more adverse reactions when N_2O was used, and one adverse reaction for the child undergoing a procedure with Midazolam. Of those reactions for N_2O, there was one episode of nausea; one described a headache; four complaints of vomiting; one had an oxygen (O_2) saturation below 92% requiring 100% O2 for recovery; and two described as having low saturations but corrected on it's own (Zier et al., 2008). The child who had an adverse

reaction to Versed had a decreased O_2 saturation that required oxygen to correct. Five of the patient's parents rated the N_2O experience better or much better than previous sedation experiences (Zier et al., 2008).

The percentage of N_2O used does not affect the rate of adverse reactions. Zier and Liu (2011) discussed the use of N_2O at concentrations up to 70% (with 30% oxygen). They found no difference in adverse reactions based on N_2O concentration percentages (Zier & Liu, 2011). However, adverse reactions did tend to increase when the administration exceeded 10 minutes (Zier & Liu, 2011). Of note, Zier and Liu (2011) found there were no time requirements for withholding food or drinks prior to sedation. Likewise, Thomas, Miller, Couloures, and Johnson (2015) found adverse reactions such as nausea and vomiting with N_2O were duration-dependent, including the possibility of delayed vomiting.

A cost-savings may occur with N_2O use, especially when delivered by an RN. Johnson, Burke, Plews, Newell, Parapia, (2008) discussed a benefit of N_2O over other forms of sedation being the low cost of the gas. In addition, delivery of N_2O by a RN required minimal monitoring, and a short recovery time may be more cost-effective than delivery and monitoring by a physician. Gourlay (2016) reported administering N_2O to women in labor cost about $25 per patient for the mask and tubing and the N_2O itself costs about $0.50 an hour. The most expensive part of N_2O administration is the scavenging system used, which is costs approximately $5,000 for each system purchased (Gourlay, 2016).

The Donnebedian framework is a method to measure outcomes for improvement. This framework utilizes three components: structure, process, and outcomes (Hickey &

Brosnan, 2017). The Plan-Do-Study-Act (PDSA) process evolved from the Donnebedian framework and is commonly utilized for outcomes measurement, especially in quality improvement. This quality improvement study utilized a PDSA cycle to obtain baseline data for the implementation of RN N_2O delivery.

Method

Design

This study was an observational, descriptive, cohort design. This was the first cycle of a PDSA to evaluate the number and types of procedures performed by credentialed RN providers when administering N_2O for minor but painful or anxiety-producing procedures in the pediatric patient. Implementation of credentialed RN providers began in the fall of 2018 from the imaging and sedation departments of a pediatric medical center. Credentialing of RN providers was established by the pediatric medical center's administration including education and training prior to implementation. A retrospective medical record review of children requiring N_2O for sedation and anxiolysis occured from October 1st, 2018 through November 30th, 2018 (with RN and physician providers) and was compared to the same time frame in 2017 (when only physician providers were used).

Setting

The setting was an approximately 200-inpatient bed pediatric medical center located in a Midwestern, urban, metropolitan area. The pediatric medical center was located in an area with over three million residents. There were three pediatric hospitals and more than six hospitals with pediatric services and inpatient beds available within the metropolitan area. This pediatric medical center was part of a network of an eight-

hospital system and served as the primary pediatric medical center for the system hospitals. The imaging and sedation departments within the pediatric medical center initiated the implementation of credentialed RNs administering N_2O for minor procedures such as magnetic resonance imaging (MRI), computerized tomography (CT), minor interventional radiology procedures, and other minor procedures needed throughout the hospital. This medical center averaged about 22 outpatient procedures a month requiring N_2O administration.

Sample

This was a convenience sample of pediatric patients with whom N_2O was used within the medical center. Inclusion criteria were those children 2-18 years of age undergoing a minor procedure using N_2O. Exclusion criteria were those under the age of two-years, those patients19-years of age or older, and those who were undergoing a procedure requiring moderate to deep sedation. Under two-years of age were excluded due to decreased ability to hold their own mask to the face.

Procedures

The pediatric medical center's administration identified five RNs in the sedation and imaging departments to complete an in-person educational program for N_2O administration by a dentist who was previously a Certified Registered Nurse Anesthetist (CRNA). The remaining department's RNs completed an online N_2O educational session. The next step towards credentialing was supervision of three N_2O administrations by a sedation physician. After successful completion, each nurse was credentialed to administer N_2O without physician supervision. Completion of RN training and credentialing was completed by January 2019. Implementation was to include two RNs

assigned to the N_2O team each day and their role included pain assistance for IV initiation and other minor procedures. In addition, a pediatric sedation credentialed physician assigned to the sedation service for the day assisted in the decision-making and ordering of the RN administered N_2O.

Data Collection/Analysis

A retrospective medical record review from October through November 2017 (physician delivery only) was compared to October through November of 2018 (RN and physician delivery). Demographic data included age, gender, and race/ethnicity. Other data such as type of procedure, type of N_2O provider, and procedure costs, which was charged by the length of time N2O was administered, was recorded. All data had personal identifiers removed and coded as 17-1, 17-2, 17-3, etc., for the 2017 data; and, 18-1, 18-2, 18-3, etc., for the 2018 data. Data was stored on a password-protected computer and flash-drive owned by the primary investigator. Data evaluation included descriptive statistics, chi-square, and paired sample t-tests for analysis.

Approval Processes

Approval from the pediatric medical center administration was obtained. Additional approvals from the DNP committee, university institutional review boards (SSM Health and the University of Missouri-St. Louis), and the university graduate school were obtained. There were minimal to no risks associated with this study since this was a retrospective medical record review and all recorded data was de-identified. The benefits of this study included an outcomes evaluation of RN and physician delivered N_2O administration.

Results

There were a total of *N*=197 patients who received N_2O during October 1st 2017 to November 30th 2017 (physician delivery only) and October 1st 2018 and November 30th 2018 (physician and RN delivery). There were 93 in 2017 (*n*=93) and 104 in 2018 (*n*=104). For the 2017 cohort, the age ranged between 2-18-years (*m*=6.72, *SD*=3.79*)*, with the most common age of 4- and 5-years, both with 15 (16%) occurrences. In the 2018 cohort, ages ranged from 2-18-years (*m*=7.73, *SD*=3.79*)*, with the most common age being 6-years and having 18 (17%) of the occurrences. A paired samples t-test compared age between the two cohorts found the difference between the two means was not statistically significant at the 0.05 level (t = -0.31, d= 0.788, p = 0.18). The frequency for gender in the 2017 cohort included more females (*n*=66; 70.97%) than males (*n*=27; 29.03%). However, in the 2018 cohort, the number of females was lower (*n*=51; 49.04%) than males (*n*=53; 51.06%). The difference between the two cohorts was not statistically significant (t= -0.31, d = 0.18, p = 0.788). the race/ethnicity demographic for the 2017 cohort revealed Whites (*n*=71; 76%) were the most frequently occurring, followed by Black (*n*=16; 17.2%), Hispanic (*n*=2; 2.15%), and Other (*n*=4; 4.3%). For the 2018 cohort, Whites remained predominant (*n*=85; 81.73%); then Black (*n*=16; 15.38%); Hispanic (*n*=1; 0.96%); and Other (*n*=2; 1.92%). The difference between the two cohorts was not statistically significant (t= 0.74, d = 0.33, p = 0.50)

The types and number of procedures in 2017 found the most common procedure was IV insertion (*n*=56; 76%), followed by botox (*n*=19; 17.2%), lab draw (*n*=3; 2.15%) voiding cystourethrogram (VCUG) catheter insertion (*n*=4; 0%); and Other (*n*=11; 4.3%). In 2018, the number of IV insertions were the most frequent procedure (*n*=52; 50%), then botox (*n*=32; 30.77%), lab draw (*n*=3; 2.88%), and VCUG catheter insertion (*n*=7;

6.73%); and Other (*n*=10; 9.62%). The most common procedure for 2017 and 2018 was IV insertions, however, the difference between the two cohorts was not statistically significant (t= -0.75, d = 0.34, p = 0.493). The administrations of N_2O in 2017 were physicians only (*n*=93; 100%), but in 2018 only 60% (*n*=63) of the gas was delivered by a physician and RN delivery was 40% (*n*=41). Comparing the number of procedures between the providers, there was essentially no difference between physician delivery and RN delivery overall (t= -0.18, d = 0.10, p = 0.857). however, for individual procedures, a credentialed RN was more likely to deliver N_2O for an IV insertion than a physician. The relationship between RN delivery and physician delivery for IV insertion was statistically significant at the .05 level (χ^2 = 23.57, $df = 4$, $p < .001$).

Finally, the charge for N_2O administration for 2017 was $140 per occurrence or for a total of $13,020 in revenue. The charge for N_2O administration in 2018 by an RN was $300 as an N_2O set-up fee since RNs were not able to charge for the service. Because of the newly discovered set-up fee, physicians were able to charge their fee for delivery ($140) plus the N_2O set-up fee ($300) resulting in a total charge of $449 when a physician delivered the gas. Hence, in 2018 the physician charges were $28,287 and RN charges were $12,300 for a combined total of $40,587 in revenue, a difference of $27,567 in potential revenue between physician only and physician or RN delivery of N_2O. Using a paired samples t test, the difference between the two cohorts was not statistically significant (t= -0.08, d = 0.04, p = 0.947).

Discussion

The addition of credentialed RNs to supplement the number of providers available to provide N_2O for pain control during minor, but painful procedures appeared to be

somewhat effective. The most common procedure N_2O was used for was IV insertion and accounted for over half of all procedures utilizing N_2O for pain control for both cohorts studied. The RN was more likely to administer the N_2O for an IV insertion than a physician ($p < 0.001$) in 2018. The comfort level of an RN when inserting an IV since RNs insert IVs much more often than physicians may explain this result. In addition, physicians were not always available when a patient was requiring an IV but the RN was usually present. Botox injections were the most common procedure facilitated by the physician as physicians usually inject botox. Hence, RN delivered N_2O may be more common with RN-related procedures and physician delivered N_2O may be more common with physician-related procedures.

The overall number of physicians versus RNs delivering N_2O for a procedure was not found to be statistically significant. The number of physician deliveries decreased when RN delivery was available in 2018. This could indicate that the availability of an RN was clinically significant to avoid a missed opportunity for pain control for minor procedures. Some procedures resulted in moderate sedation by the physician if N_2O was deemed to not be enough in controlling pain, such as the use of Versed or Propofol, this might have accounted for the decrease in physician availability. Having an RN available for administering N_2O for a minor, but painful procedure appeared to maintain the number of children receiving pain control in 2018 when compared to 2019.

Finally, the financial cost of N_2O administration by a physician provider when compared to an RN provider was difficult to assess due to a change in charge structure. In 2017 the average charge of $140 was issued when N_2O was given by a physician; resulting in $13,020 in charges. In 2018, the discovery of an allowed N_2O “set-up” fee of

$300 allowed for the physician delivery charge ($140) plus the N_2O set-up fee ($300) to increase the total charge for physician delivery to $449 per occurrence; therefore, in 2018, physicians charged $28,287 for services. The RN could only charge for the N_2O set-up fee; hence, the RN charges in 2018 were $12,300. The total charged in 2018 (physician and RN charges) resulted in $40,587 being issued. A difference of $27,567 was found between 2017 and 2018 with the discovery of the N_2O set up fee and supplemental RN deliveries of the gas.

Implications for practice would include the continued addition of N_2O being administered by nursing staff and physicians. There were still more pediatric patients reached in fall of 2018 versus fall of 2017, though this was not statistically significant. The department should create nursing only appointments for those who are having routine procedures that have already successfully been performed under N_2O. By adding this type of appointment, they are creating more availability for reaching pediatric patients undergoing painful procedures.

In the future, this project could be repeated to include four or more months of data. This may give a better representation of what the addition of the nursing staff did. The data may have been collected too early during the implementation process of this protocol, not allowing every RN in the department to become N_2O certified, decreasing the utilization by an RN. If repeated, results can be compared, as there is no data currently published reviewing these changes.

Conclusion

In conclusion, the addition of credentialed RNs to deliver N_2O to children undergoing minor, but painful procedures may have improved physician availability to provide other types of needed sedation. Hence, the addition of RN facilitated delivery may have decreased the number of missed opportunities for pediatric pain control. Further, charges incurred from the combined efforts of physician and RN delivery of N_2O improved when the N_2O set up fee was discovered. Providing N_2O for pediatric minor, but painful procedures may be enhanced when RNs are credentialed to deliver the gas.

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Appendix A

Table 1.

Demogrphics for 2017 Patients

Variable	*n*	%	Cumulative %
Procedure			
IV	56	60.22	60.22
Botox	19	20.43	80.65
Lab Draw	3	3.23	83.87
VCUG/Catheter	4	4.30	88.17
Other	11	11.83	100
Provider			
Physician	93	100	100
Age of Patient			
2	7	7.53	7.53
3	8	8.60	16.13
4	15	16.13	32.26
5	15	16.13	48.39
6	9	9.68	58.06
7	10	10.75	68.82
8	10	10.75	79.57
9	3	3.23	82.80
11	3	3.23	86.02
13	3	3.23	89.25
14	6	6.45	95.70
15	1	1.08	96.77
16	2	2.15	98.92
18	1	1.08	100
Race/Ethnicity			
White	71	76.34	76.34
Black	16	17.20	93.55
Hispanic	2	2.15	95.70
Other	4	4.30	100

Variable	*n*	%	Cumulative %
Gender			
Female	66	70.97	70.97
Male	27	29.03	100

Appendix B

Table 2.

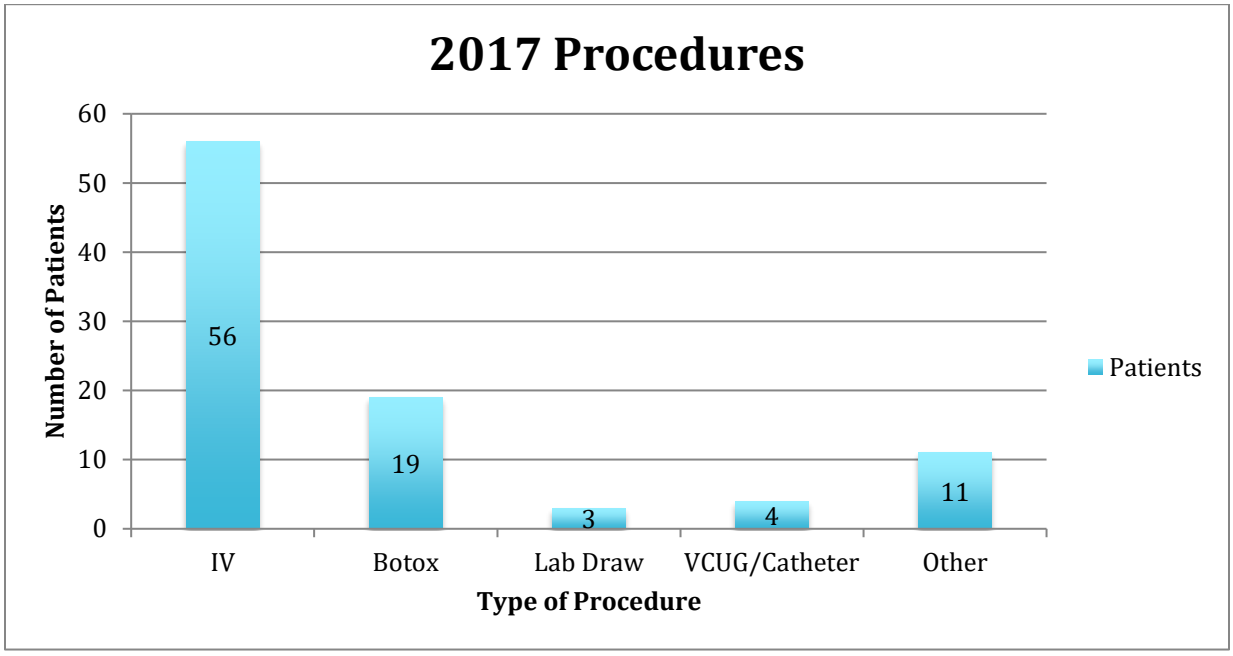
Demographics for 2018 Patients

Variable	*n*	*%*	Cumulative *%*
Procedure			
IV	52	50	50
Botox	32	30.77	80.77
Lab Draw	3	2.88	83.65
VCUG/Catheter	7	6.73	90.38
Other	10	9.62	100
Provider			
RN	41	39.42	39.42
Physician	63	60.58	100
Age of Patient			
2	3	2.88	2.88
3	7	6.73	9.62
4	8	7.69	17.31
5	13	12.50	29.81
6	18	17.31	47.12
7	10	9.62	56.73
8	10	9.62	66.35
9	9	8.65	75
10	8	7.69	82.69
11	2	1.92	84.62
12	2	1.92	86.54
13	1	0.96	87.50
14	4	3.85	91.35
15	3	2.88	94.23
16	3	2.88	97.12
17	1	0.96	98.08
18	2	1.92	100
Race/Ethnicity			
White	85	81.73	81.73

Variable	*n*	*%*	Cumulative *%*
Black	16	15.38	97.12
Hispanic	1	0.96	98.08
Other	2	1.92	100
Gender			
Female	51	49.04	49.04
Male	53	50.96	100

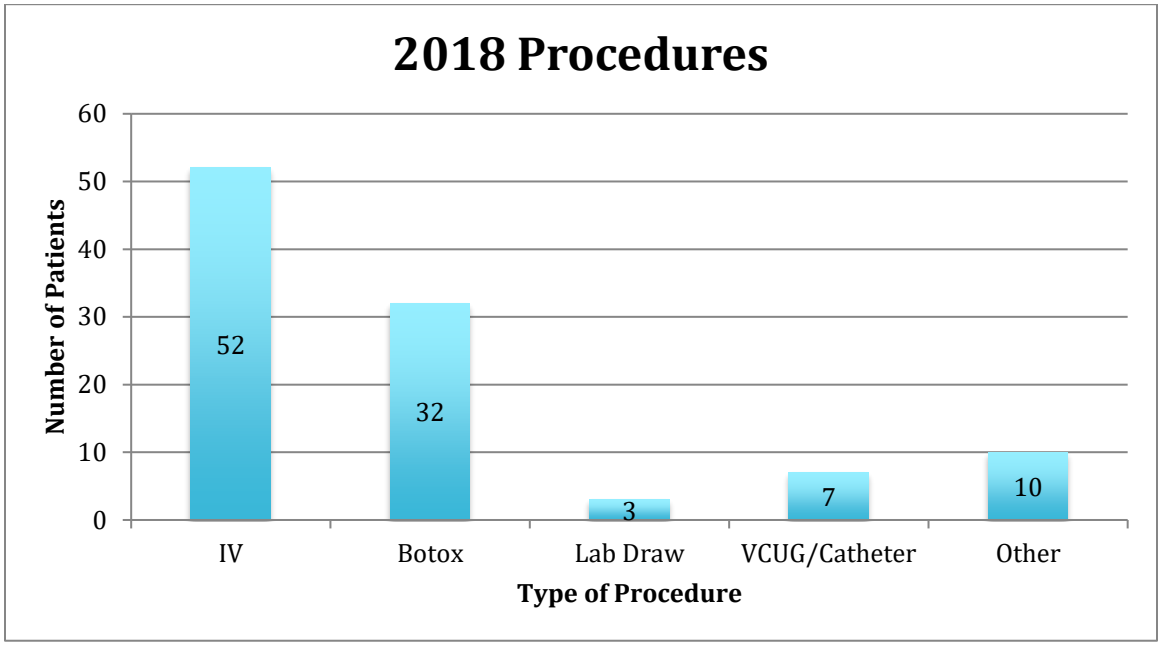
Appendix C

Figure 1: 2017 Procedure Frequencies



Appendix D

Figure 2: 2018 Procedure Frequencies



Appendix E

Table 3.

Observed and Expected Frequencies of Procedure vs Provider

	Provider				
Procedure	RN	Physician	χ^2	*df*	*p*
IV	32[20.50]	20[31.50]	23.57	4	< .001
Botox	8[12.62]	24[19.38]			
Lab Draw	0[1.18]	3[1.82]			
VCUG/Catheter	0[2.76]	7[4.24]			
Other	1[3.94]	9[6.06]			

Credentialed RNs were more likely to deliver N_2O for an IV insertion than a physician. The relationship between RN delivery and physician delivery was statistically significant at the .05 level ($\chi^2 = 23.57$, $df = 4$, $p < .001$).